Appendix A. EGS Support of EOS-Related Missions

This appendix describes the various missions related to the EOS program but not specifically dedicated to EOS. These EOS-related missions include spacecraft from non-EOS programs flying some instruments that are dedicated to the EOS program. Figure A-1 provides an overview of EOS related systems and interfaces supporting the TRMM, Landsat-7, and ADEOS-II missions.

A.1 Tropical Rainfall Measuring Mission

TRMM is a joint NASA/NASDA mission designed to advance understanding of total rainfall and the rate of rainfall in the tropics. The TRMM satellite carries both NASA and Japanese instruments. EOSDIS ingests and archives TRMM data products and instrument data. Figure A-2 provides an overview of the TRMM data flow and interfaces.

The TRMM ground support component provides data collection and analysis services for the TRMM project. The following instruments are planned to fly on the TRMM Spacecraft:

- CERES Cloud and Earth Radiant Energy System
- LIS Lightning Imaging Sensor
- PR Precipitation Radar
- TMI TRMM Microwave Imager
- VIRS Visible Infrared Scanner

The TRMM ground support facilities provide data collection, analysis, and product generation services for PR, TMI, and VIRS instruments. These data and data products are then sent to the DAACs for archival and distribution.

Additionally, the TRMM ground support facilities also provide data collection services for two EOS instruments (CERES and LIS) flying on the TRMM spacecraft. These data are then provided to the LaRC DAAC and the LIS SCF, respectively, for data analysis, product generation, archival, and distribution services. The DAACs, using EOSDIS capabilities and people, are responsible for distributing these data and products to the respective science teams and users.

The TRMM ground support services are provided by two elements, the SDPF and TSDIS. The ground facility for capturing TRMM data is the SDPF, which is a multiproject facility located at GSFC. The SDPF is a Level 0 ground system designed to capture and process packet telemetry data that adhere to packet forms prescribed by the CCSDS recommendations. The TRMM science data undergoes Level 0 processing at the SDPF, and it is then forwarded for Level 1 through Level 4 processing to the appropriate data analysis and archive facility.

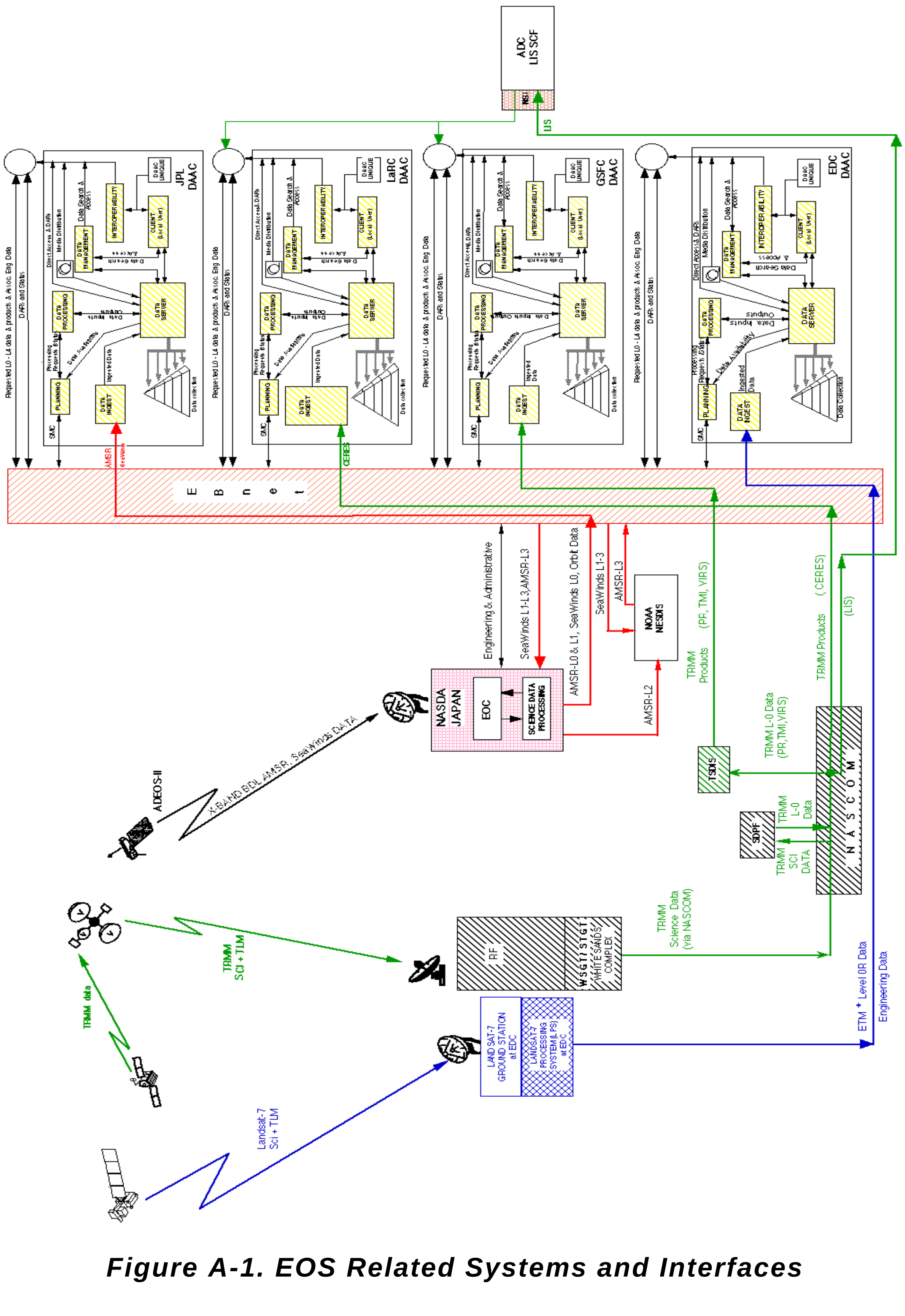

Figure A-1. EOS Related Systems and Interfaces

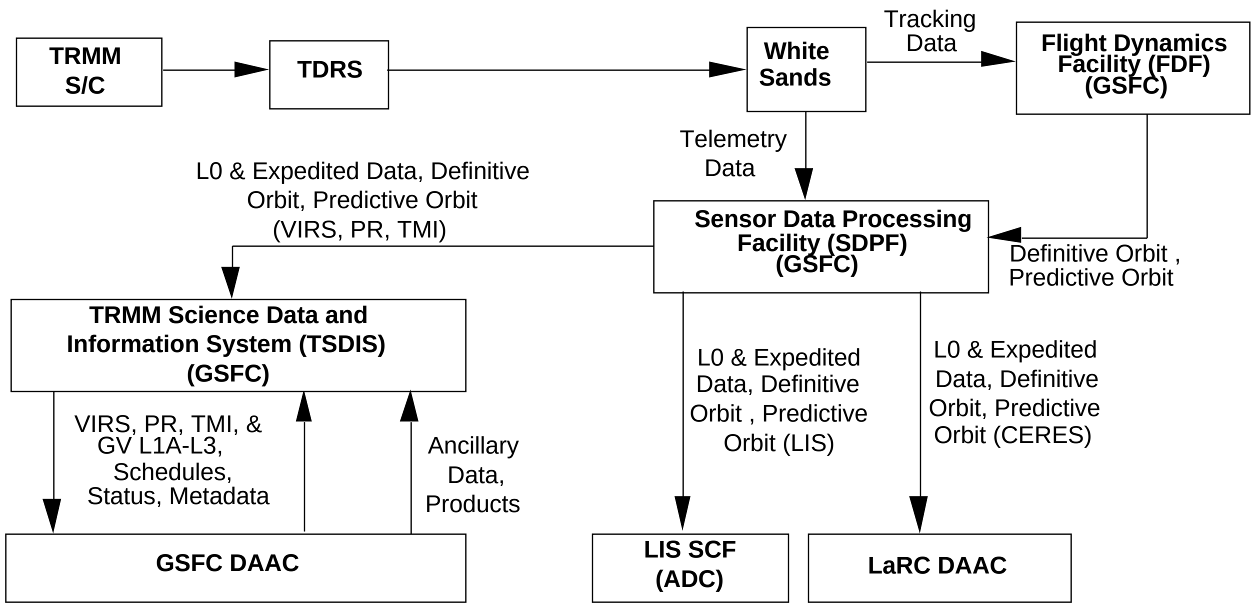

Figure A-2. TRMM Data Flow

The TSDIS is responsible for science planning and instrument monitoring coordination. It is also responsible for higher level processing of production data products for PR, TMI, and VIRS. Ancillary ground truth data and data from supporting field experiments required for data processing and validation are stored at TSDIS. Data products generated by TSDIS are available to the TRMM science team via the TRMM Science Network.

TSDIS forwards PR, TMI, and VIRS data products to the TRMM Science Team as requested or predefined and, after release approval by the TRMM Science Team, to the GSFC DAAC for archiving and subsequent distribution to the Science Team and general users. The Lightning Imaging Sensor (LIS) SCF provides ancillary ground truth data and data from supporting field experiments to the DAACs and other users.

A.2 Landsat-7

The Landsat-7 ground support components provide distribution and user interface services. Figure A-3 shows the ground support components and Landsat-7 data flow.

The major functions of the Landsat-7 Ground Station (LGS), located at the EDC in Sioux Falls, SD, are the capture and recording of the wideband data via direct X-band downlinks. The data are routed to the LPS.

Upon receiving the wideband data from the LGS, the LPS processes the data to create Level 0R files. These processed files are stored temporarily at the LPS and sent to the EDC DAAC for archive and further processing. Included in this file set are engineering data, browse data to

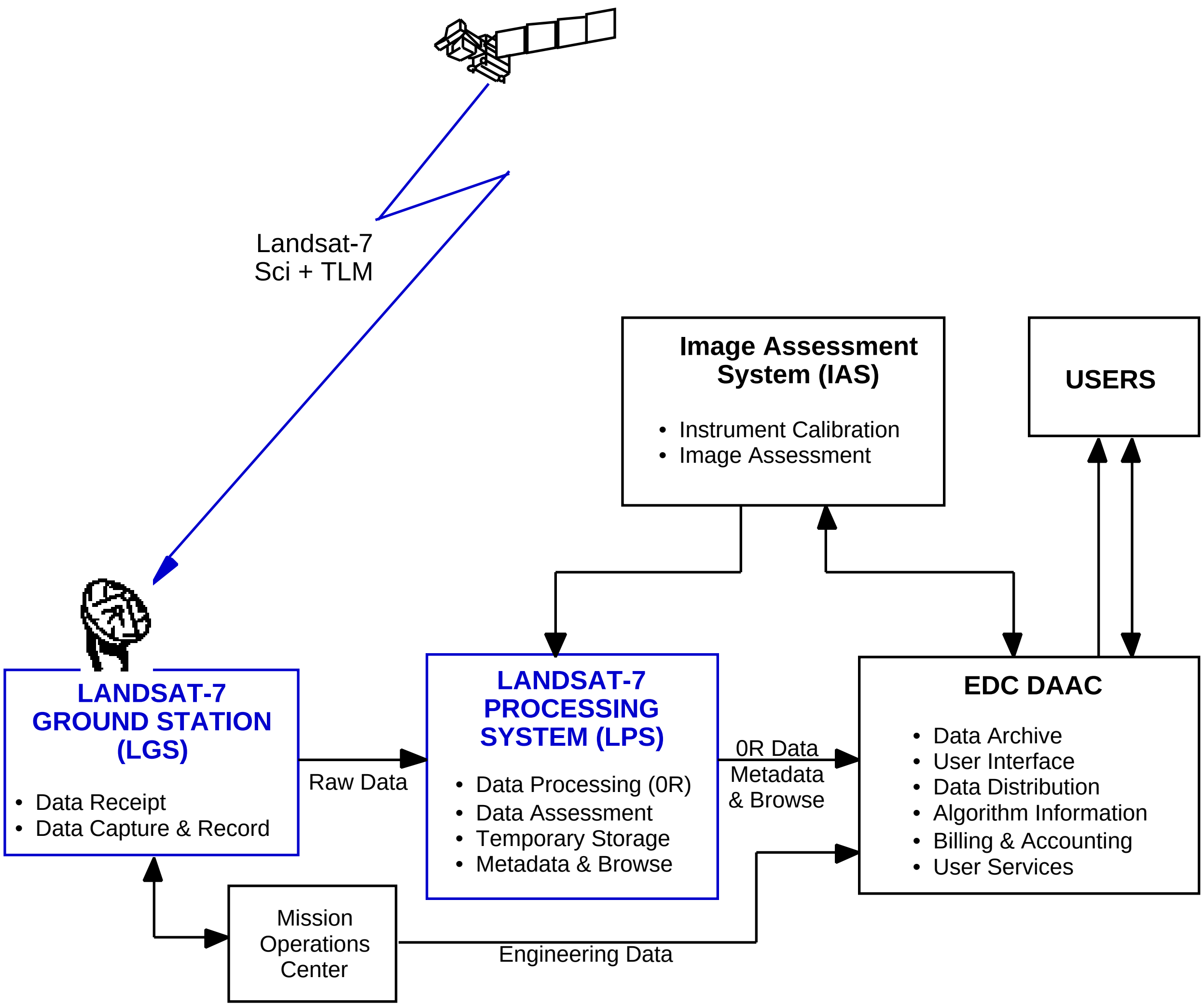

Figure A-3. Landsat-7 Ground Components

support user viewing of the imaged area, and metadata that provides various scene information, including cloud cover assessments and data quality evaluations.

The EDC DAAC interacts with the user community and provides access to Landsat-7 data. The primary interface to the user is via electronic networks, but voice and mail communications are also available. The EDC DAAC interacts with the IAS, distributing ordered data for system evaluation and receiving updated calibration data and its associated metadata.

The IAS is responsible for offline assessment of image quality to ensure compliance with the radiometric and geometric requirements of the spacecraft and ETM+ sensor throughout the life of the mission. The IAS receives Level 0R data and/or ancillary information such as payload correction data, housekeeping data, and browse and metadata from the LPS and the EDC DAAC. These data are assessed in raw form or processed to Level 1R and 1G in IAS and assessed with respect to their geometric, radiometric, and image attract qualities. Trend analysis is conducted. Calibration tables updates and trend analyses reports are passed to the EDC DAAC and IGSs. Anomalies are reported to the mission operations center (MOC) and the LPS.

A.3 Advanced Earth Observing Satellite

ADEOS I will have the following instruments:

- AVNIR¾ Advanced Visible and Near-Infrared Radiometer
- IMG¾ Interferometric Monitor for Greenhouse Gases
- NSCAT¾ NASA Scatterometer
- OCTS¾ Ocean Color and Temperature Scanner
- POLDER¾ Polarization and Directionality of Reflectances
- TOMS¾ Total Ozone Mapping Spectrometer

The ADEOS-I spacecraft will be launched by NASDA (Japan) later in 1996, containing instruments from NASDA, MITI, and EA in Japan; the NSCAT (JPL) and TOMS (GSFC) instruments from the United States; and POLDER from CNES. The ADEOS spacecraft orbits the Earth approximately 14 1/4 times per day. Of these orbits, 10 are typically in range of Fairbanks (ASF); 4, of Wallops (WFF); and 4, of the EOC in Hatoyama, Japan. All three sites capture the raw data during satellite passes from tape recorders aboard the ADEOS spacecraft and send these data to the NASDA ADEOS receiving system, also at Hatoyama. The EOC data are sent by LAN, while the data from the two U.S. receiving sites are recorded on tape and mailed to NASDA.

ADEOS II will have the following instruments:

- SeaWinds¾ Advanced NSCAT
- HIRDLS¾ High-Resolution Dynamics Limb Sounder (Candidate)
- TOMS¾ Total Ozone Mapping Spectrometer (Candidate)

NASDA (Japan) will launch the ADEOS II spacecraft in 1999. NASDA will provide operational control and primary data capture. Figure A-1 provides an overview of the ADEOS-II data flow and interfaces.

Appendix B. Additional EOS Information

B.1 EOS Spacecraft and Science Instruments

EOS is a long-term program to provide continuous observations of global climate change. Repeating flights of the principal EOS spacecraft on 6-year centers will ensure adequate coverage for at least 15 years; however, payloads of the follow-on EOS spacecraft could change, depending on the evolution of scientific understanding and the development of technology.

The EOS Program currently includes nine spacecraft; three morning Sun-synchronous (EOS AM series), three afternoon Sun-synchronous (EOS PM series), and three afternoon Sun-synchronous polar (EOS CHEM series). The EOS AM, PM, and CHEM spacecraft will be placed into 98.2 degree inclined, 705-km, 16 day, 233-orbit repeat cycles, with the EOS AM series having a 10:30 a.m. descending node crossing; the EOS PM series having a 1:30 p.m. ascending node crossing; and the EOS CHEM series, a 1:45 p.m. ascending node crossing. Three smaller spacecraft of the EOS Radar ALT series will be placed into non-Sun-synchronous high-inclination orbits (66 degrees, similar to TOPEX). Medium-light spacecraft of the EOS Laser ALT series will be placed into non-Sun-synchronous orbits at a 94-degree inclination. The SAGE III series will be placed into a high-inclination orbit on the Meteor 3M-1 spacecraft and onto a 57.1-degree inclination orbit on the Space Station.

All spacecraft but the AM-1 will be functionally identical, taking advantage of a common spacecraft bus design to reduce total program cost. The PM-1 spacecraft will be the first to use the common bus design. Figure B-1 summarizes the current EOS mission profile.

The Moderate-Resolution Imaging Spectroradiometer (MODIS) facility instrument is a medium-resolution, cross-track scanning radiometer to measure biological and physical processes. It consists of 36 spectral bands from the visible to the infrared. The presence of MODIS on both the EOS AM and PM spacecraft proves central to the program by providing complete global ocean color measurements through avoidance of Sun glint over the northern oceans and the lack of illumination over the southern oceans. By taking further advantage of the complementary ascending and descending orbits of the AM and PM spacecraft, MODIS provides diurnal sampling coverage and also provides the cloud observations needed to interpret CERES radiation budget measurements, which are also collected by both spacecraft.

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) facility instrument is an imaging radiometer provided by Japan. It will provide high-resolution images of the land surface, water, ice and clouds using 14 spectral bands from the visible through the infrared. The Multi-Angle Imaging Spectroradiometer (MISR) uses CCD cameras and four spectral bands to measure top-of-atmosphere, cloud and surface angular reflectance. Measurements of Pollution in the Troposphere (MOPITT) is a four-channel correlation spectrometer with cross-track scanning.

SAGE III will provide observation of aerosols and temperature from two different orbits. Ocean primary productivity observations are being obtained via a data purchase from the Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) onboard the SeaStar spacecraft.

While the majority of the EOS data users are expected to obtain their data from the EOSDIS, real-time MODIS data from the EOS AM series of spacecraft, as well as the entire real-time data stream of the EOS PM series of spacecraft, will be broadcast directly to the ground and available to anyone within line-of-sight of these spacecraft. The data may be received, without charge, by anyone who has obtained or constructed an appropriate ground station.

This Direct Broadcast service will require a moderately sophisticated ground station capable of receiving the signal (a tracking 3-m dish antenna operating in the X-band of 8025-8400 MHz), capturing the data at a rate of 13.125 Mbps for EOS AM-1 (slightly higher for the PM-1 series), and providing all the data processing necessary to produce a usable product. NASA will provide the information necessary to procure or build and operate such a station, but has no responsibility to provide the funding to do so.

B.2 AM-1 Mission Characteristics

Planned for launch in June 1998, the EOS AM-1 flight includes five instruments to be placed into a polar, Sun-synchronous, 705-km orbit by an Intermediate Expendable Launch Vehicle. The launch will take place from the Western Space and Missile Center. The payload consists of ASTER, CERES (dual scanners), MISR, MODIS, and MOPITT.

EOS AM-1 will have an equatorial crossing time of 10:30 a.m., when daily cloud cover is typically at a minimum over land such that surface features can be more easily observed. The instrument complement is intended to obtain information about the physical and radiative properties of clouds (ASTER, CERES, MISR, MODIS); air-land and air-sea exchanges of energy, carbon, and water (ASTER, MISR, MODIS); measurements of important trace gases (MOPITT), and volcanology (ASTER, MISR, MODIS). CERES, MISR, and MODIS are provided by the United States; MOPITT is provided by Canada; and ASTER is provided by Japan. The EOS AM-1 spacecraft design (Figure B-2) will support an instrument mass of 1,155 kg, an average power for spacecraft and instruments of 2.5 kW (3.5 kW peak), and an average data rate of 18 Mbps (109 Mbps peak). Onboard solid-state recorders will collect at least one orbit's data for playback through TDRSS, even though a playback on each orbit is planned.

The EOS AM-1 spacecraft will also include the Direct Access System (DAS), which is composed of the Direct Playback subsystem, the Direct Broadcast Subsystem, and the Direct Downlink subsystem. AM-1 data will be recorded and played back via TDRSS, and DAS will provide a backup option for direct transmittal of onboard data to ground receiving stations via an X-band transmitter should the satellite lose its TDRSS link. DAS will also support transmission of data to ground stations of qualified EOS users around the world who require direct data reception. These users fall into three categories:

1. EOS team participants and interdisciplinary scientists who require real-time data to conduct or validate flight observations, to plan aircraft campaigns, or to observe rapidly changing conditions in the field

2. International meteorological and environmental agencies that require real-time measurements of the atmosphere, storm and flood status, water temperature, and vegetation stress

3. International partners who require receipt of data from their high-volume EOS instruments at their own analysis centers for engineering quality checks and scientific studies

The Direct Broadcast subsystem will broadcast MODIS data at 13 Mbps. At this rate, properly equipped ground stations can receive, process, and display the swath data as the EOS spacecraft passes within range.

The EOS AM-1 spacecraft is being developed for NASA by the Lockheed-Martin facilities at East Windsor, New Jersey, and Valley Forge, Pennsylvania. The contractor performs design, construction and testing of the AM-1 spacecraft, provides a spacecraft simulation capability, and provides spacecraft analysis software and data base parameters to the EOC.

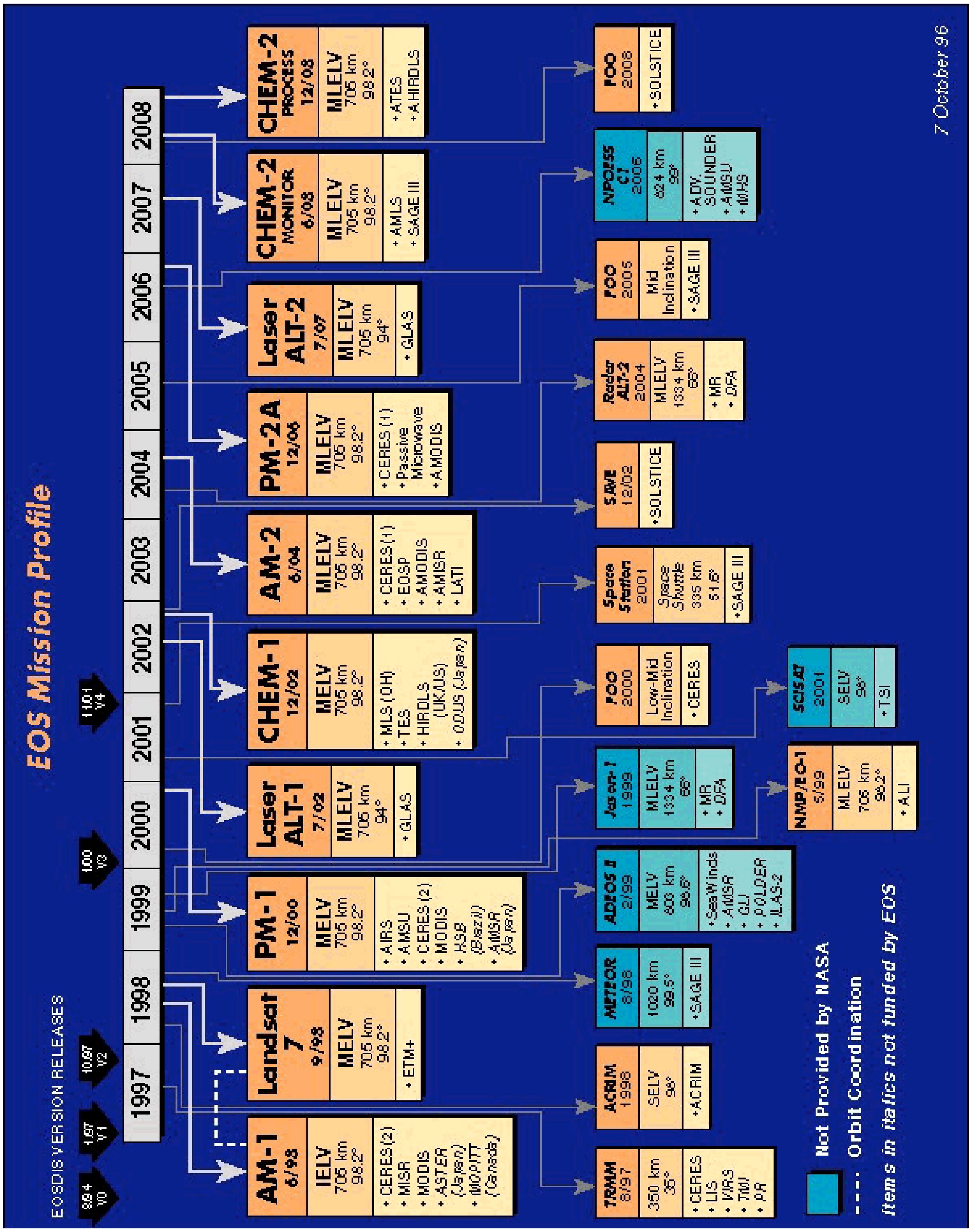

Figure B-1. EOS Mission Profile

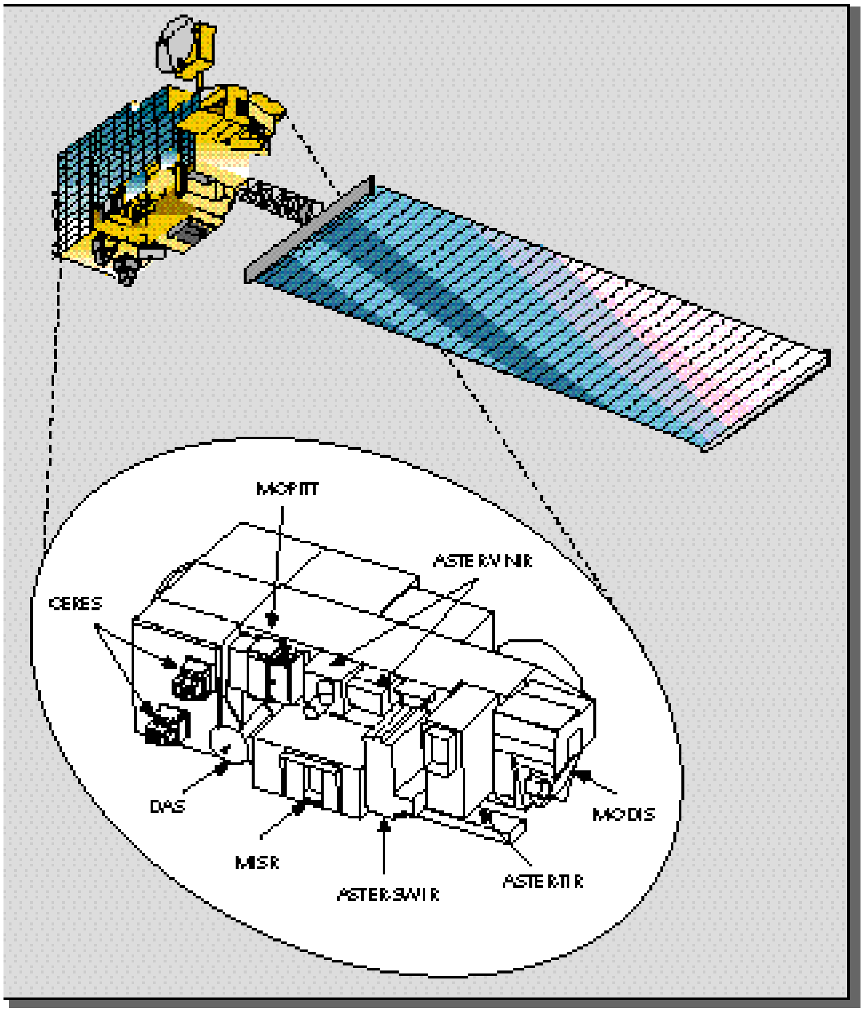

Figure B-2. Payload